

# Smoke Monitoring from Space

Melanie Follette-Cook, Pawan Gupta, and Bryan Duncan

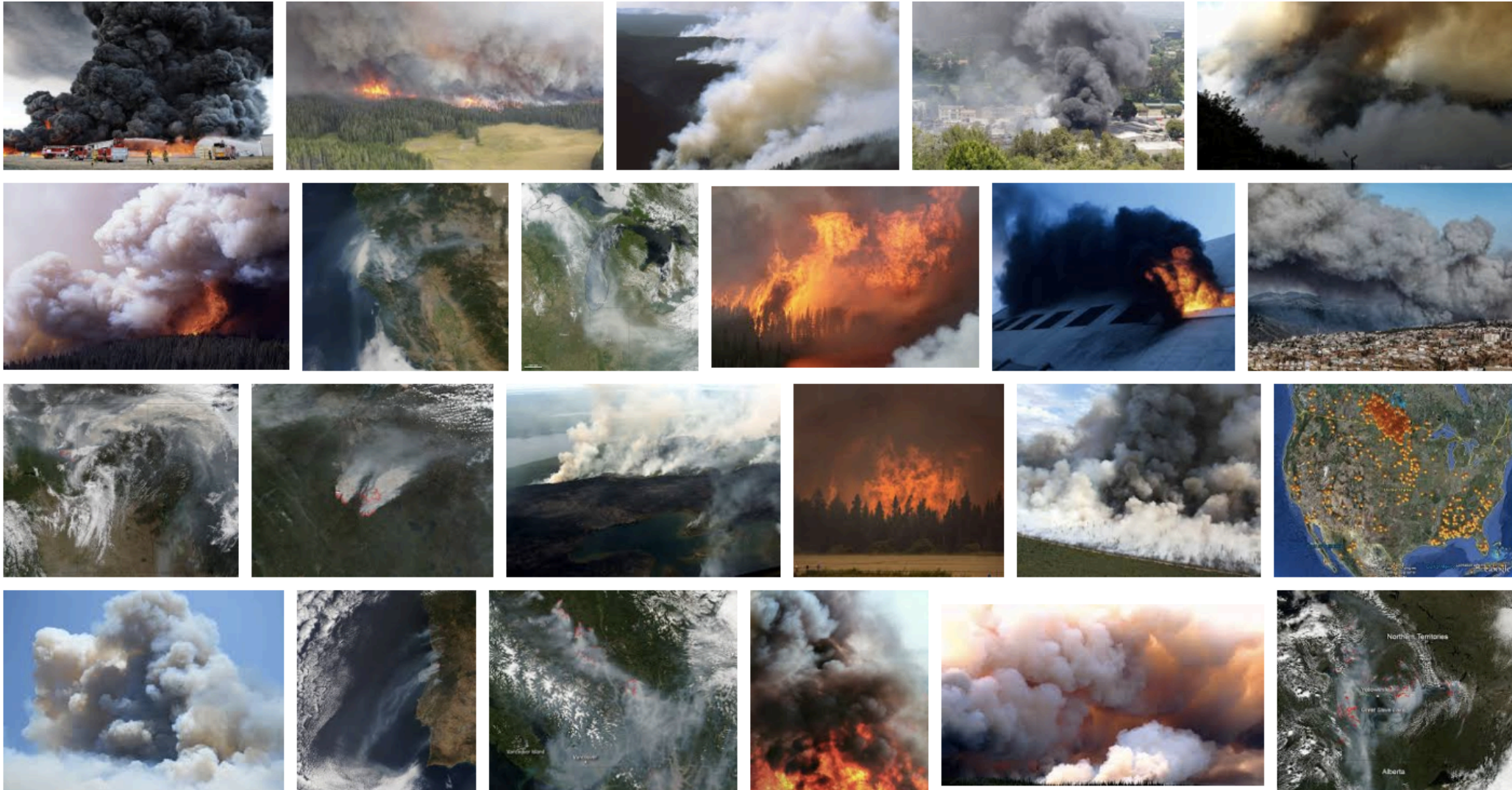
NASA Remote Sensing for Air Quality Applications, March 20-23, 2018, Jakarta, Indonesia

# Learning Objectives

By the end of this presentation, you will be able to:

- describe existing satellite capabilities for smoke monitoring
- describe available smoke products and their applications

# Fires in Pictures – Google Image Search



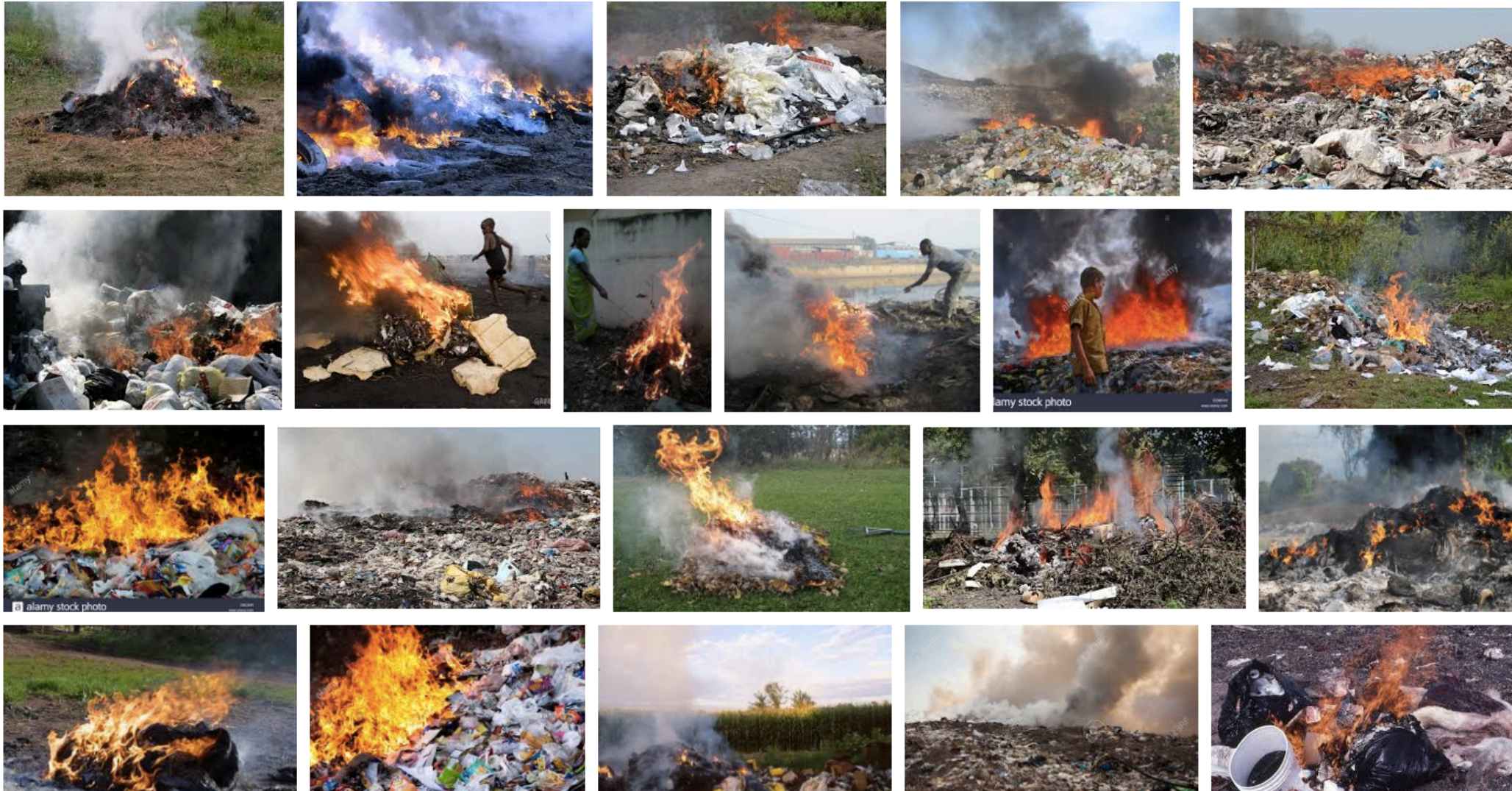
# Forest Fires in Pictures - Google Image Search



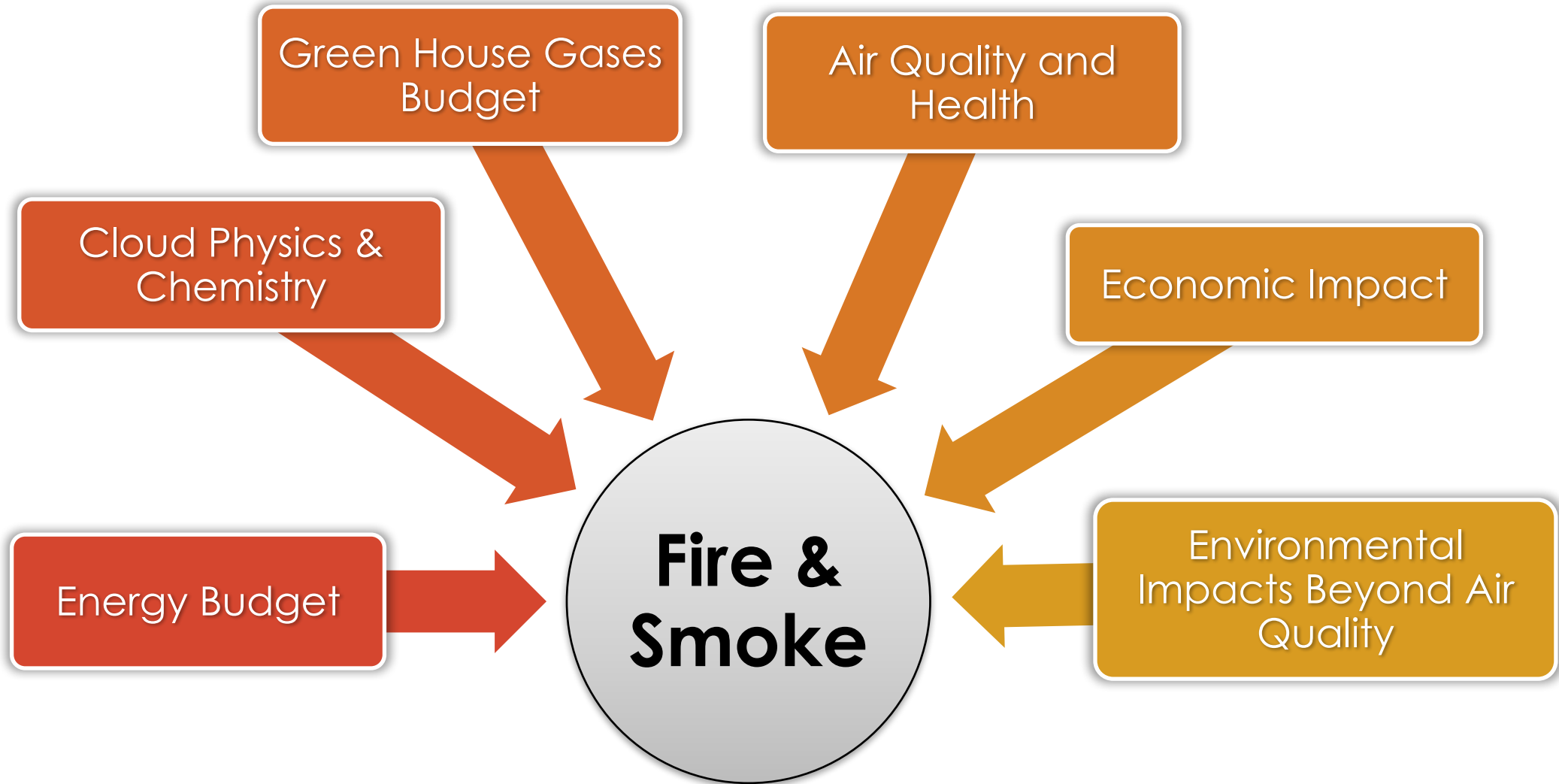
# Agriculture Fires in Pictures - Google Image Search



# Waste Burning in Pictures - Google Image Search

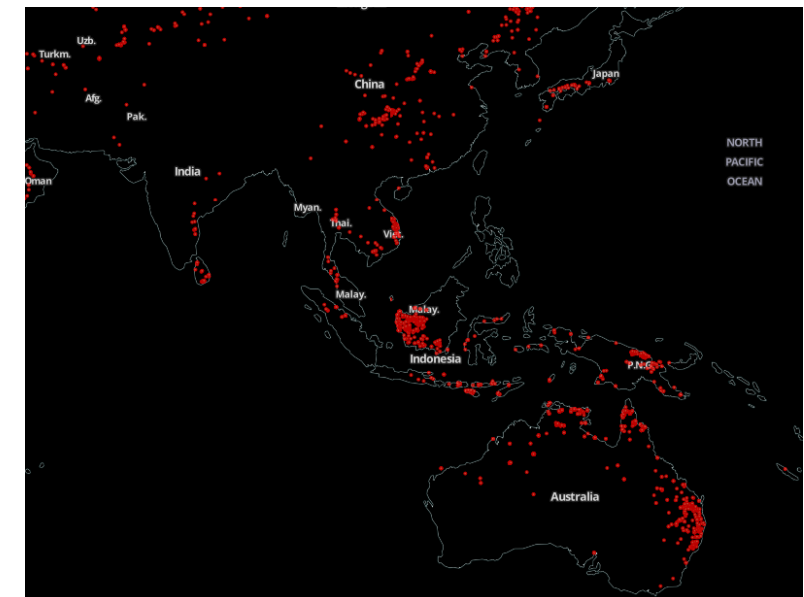
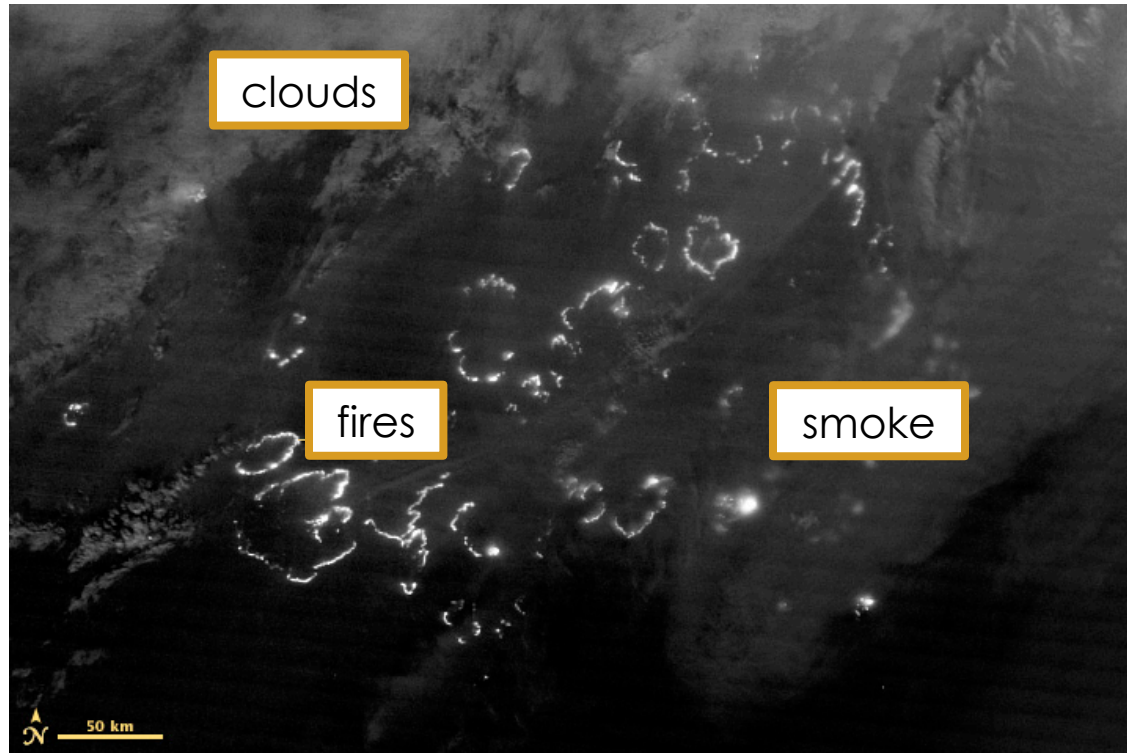


# Importance of Smoke and Fire Monitoring

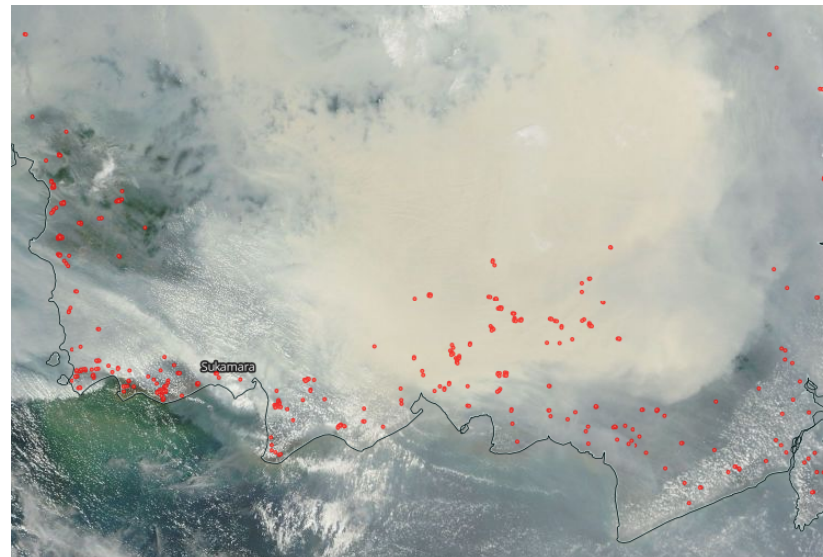
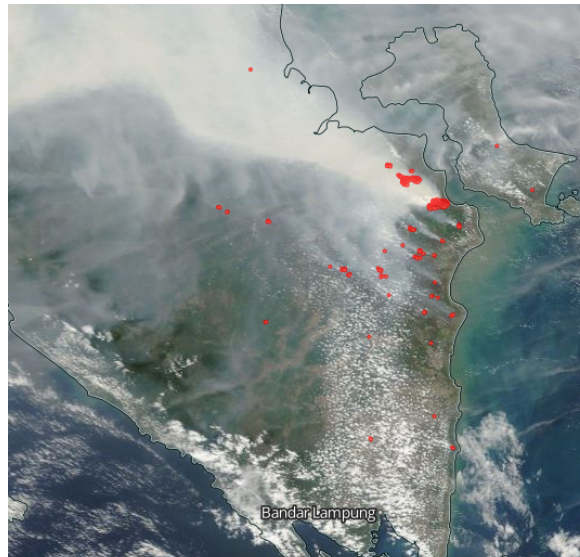
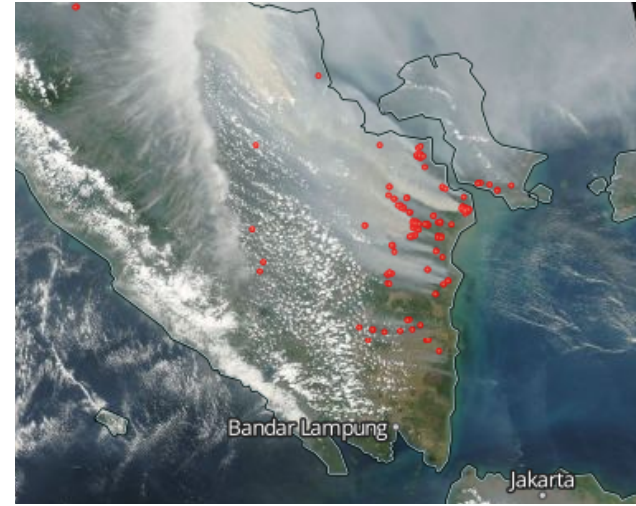
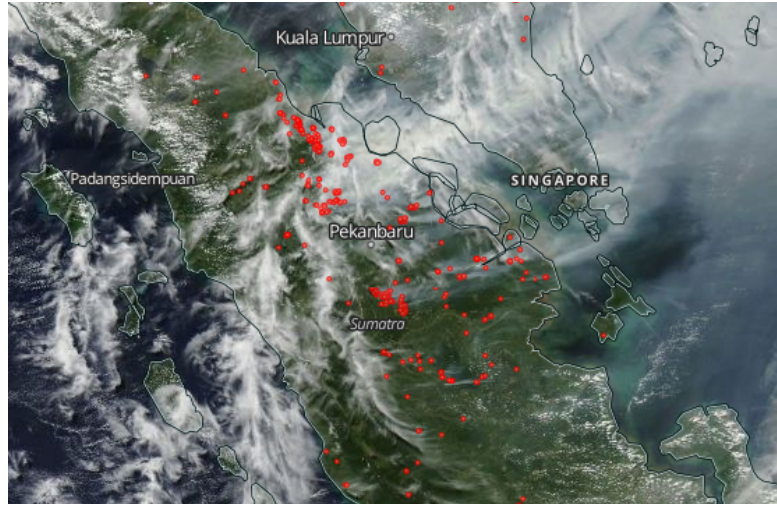


# Fire Detection From Satellites

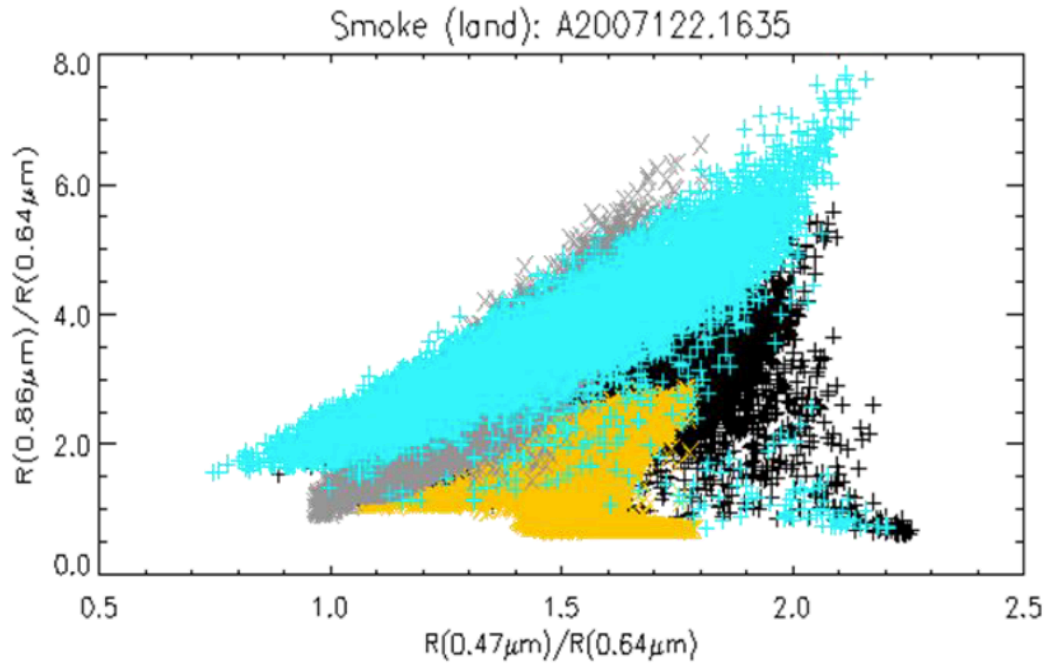
- By detecting smoke
- By detecting temperature anomaly
- By detecting light



# Visible Smoke From Fires



# Spectral Signatures - Smoke Over Land

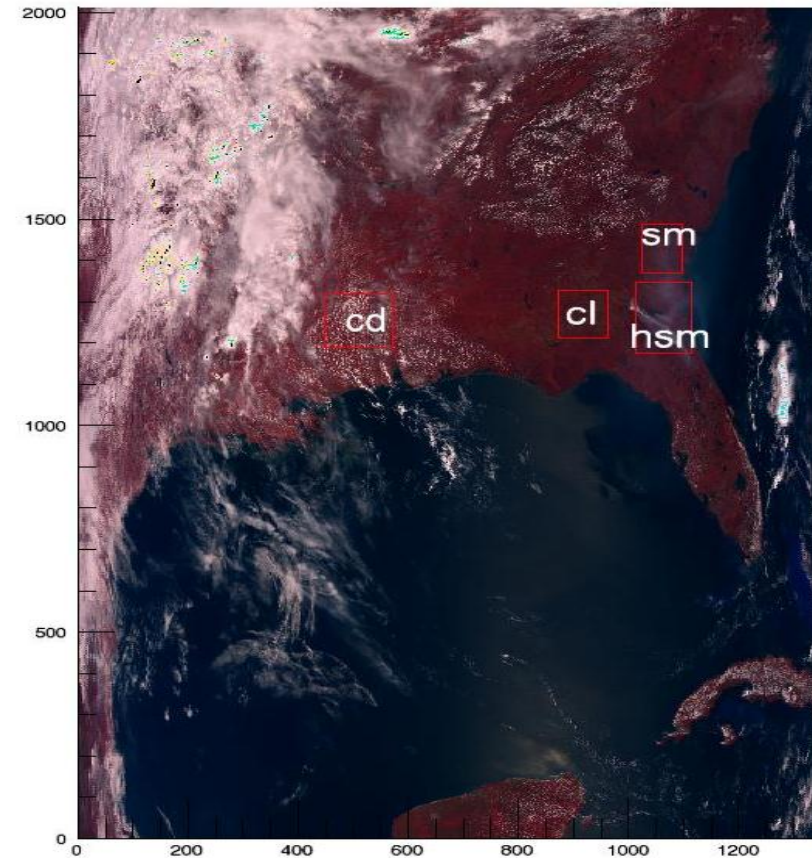


Clear sky  
Smoke  
Heavy smoke  
Clouds

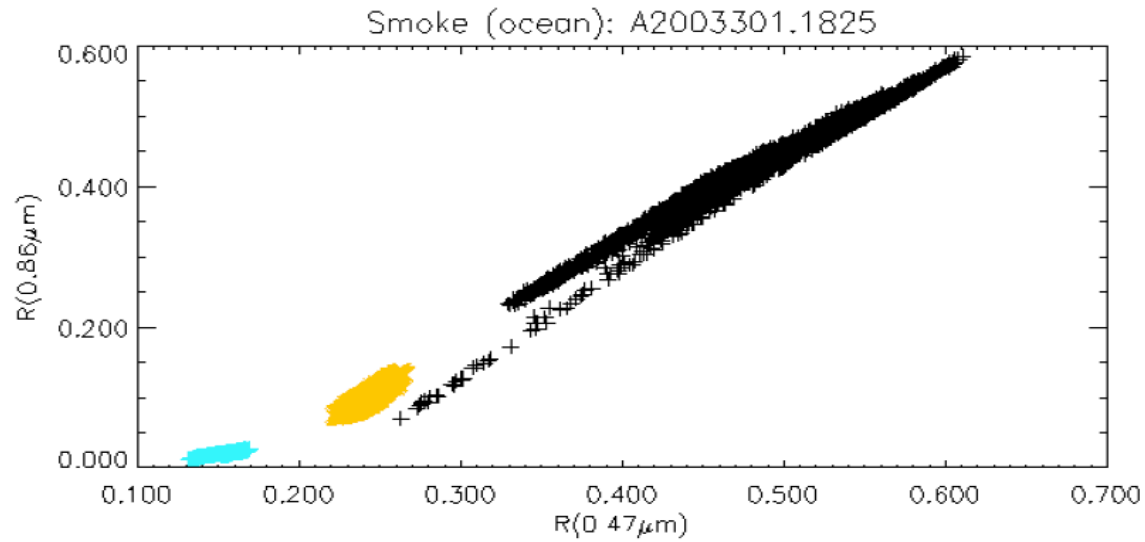
Zhao et al., 2010

Smoke Case (May 2, 2007; 16:35UTC; Terra)

RGB (2007122.1635)

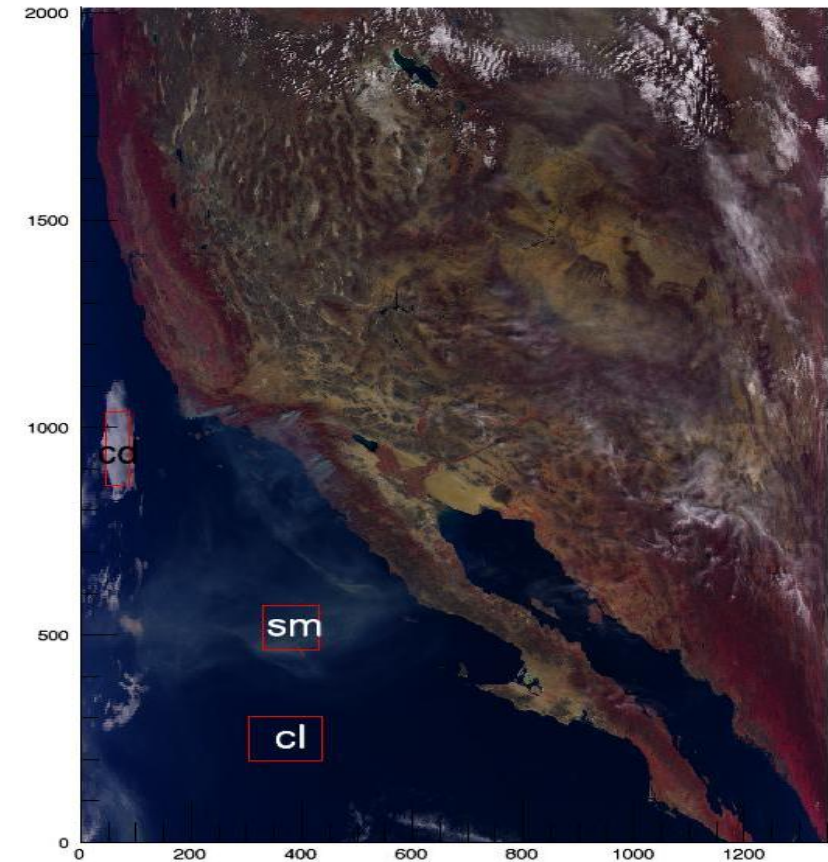


# Spectral Signatures - Smoke Over Ocean

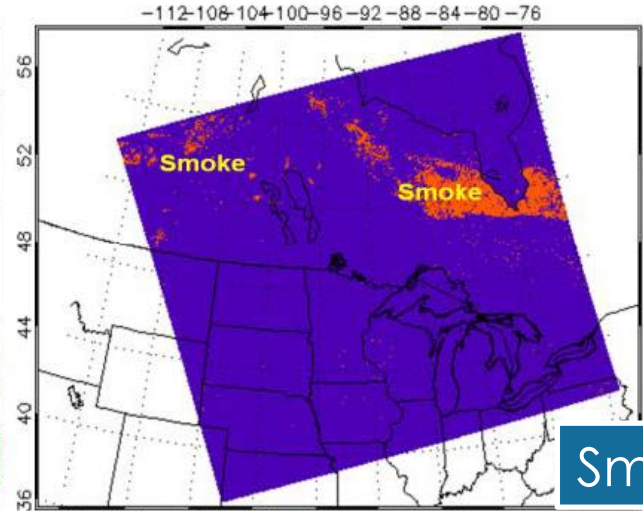


Clear sky  
Cloud  
Smoke

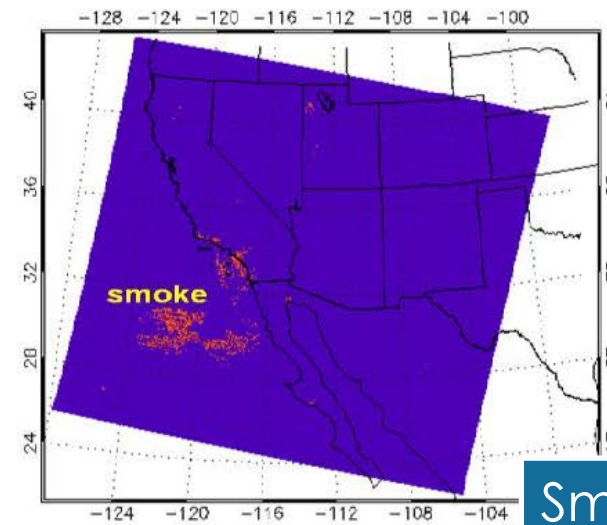
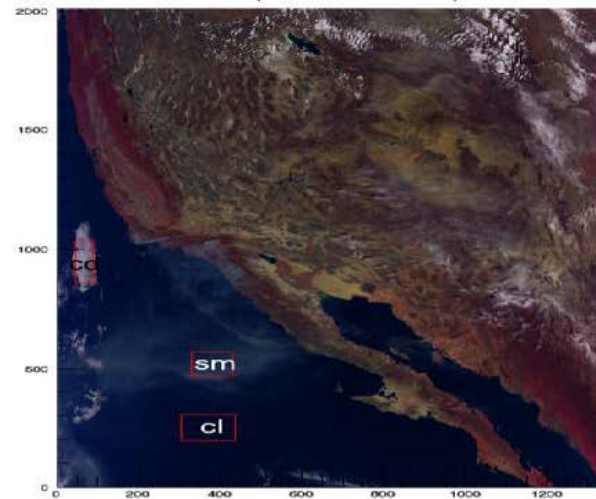
Smoke Case (Oct. 28, 2003; 18:25UTC; Terra)  
RGB (2003301.1825)



# Smoke Detection Example (Zhao et al., 2010)



Smoke Over Land

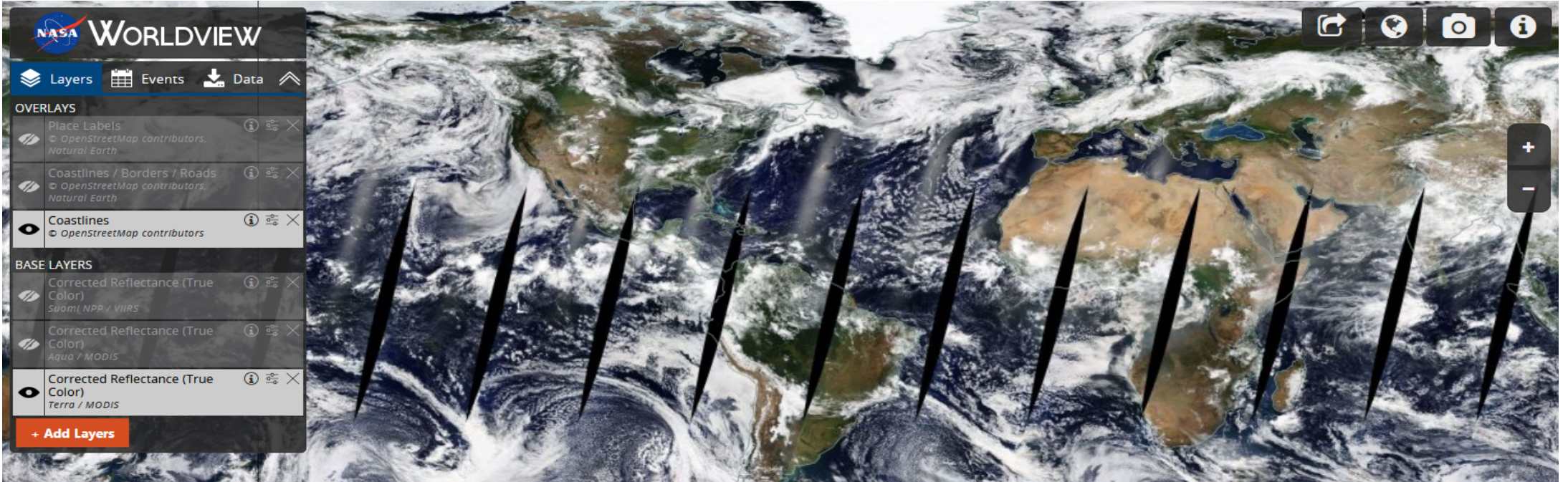


Smoke Over Water



# Smoke Monitoring Tools – Worldview

## NRT Data & Image Access

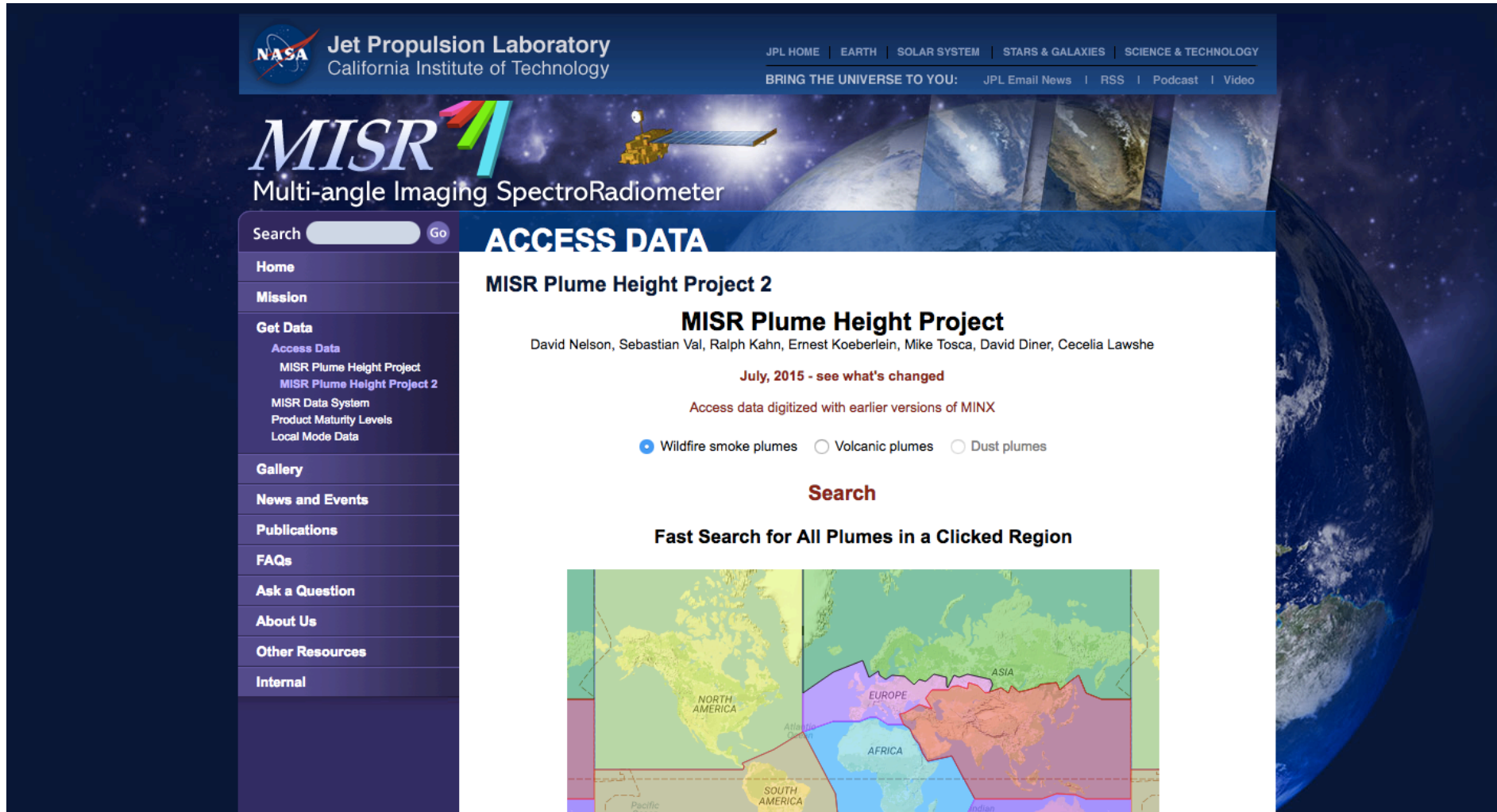


- Visible Imagery (MODIS, VIIRS)
- Fire Detection (MODIS, VIIRS)
- Aerosol Optical Depth (MODIS, OMI, MISR)
- Aerosol Index (OMI)
- Day-Night Band (VIIRS)



# Smoke Monitoring Tools – MISR Plume Height

<https://misr.jpl.nasa.gov/getData/accessData/MisrMinxPlumes2/>



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# MISR

Multi-angle Imaging SpectroRadiometer

Search  Go

**ACCESS DATA**

## MISR Plume Height Project 2

### MISR Plume Height Project

David Nelson, Sebastian Val, Ralph Kahn, Ernest Koeberlein, Mike Tosca, David Diner, Cecelia Lawshe

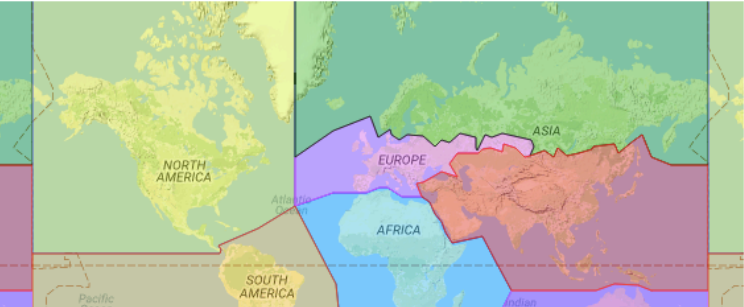
July, 2015 - see what's changed

Access data digitized with earlier versions of MINX

☒ Wildfire smoke plumes ☐ Volcanic plumes ☐ Dust plumes

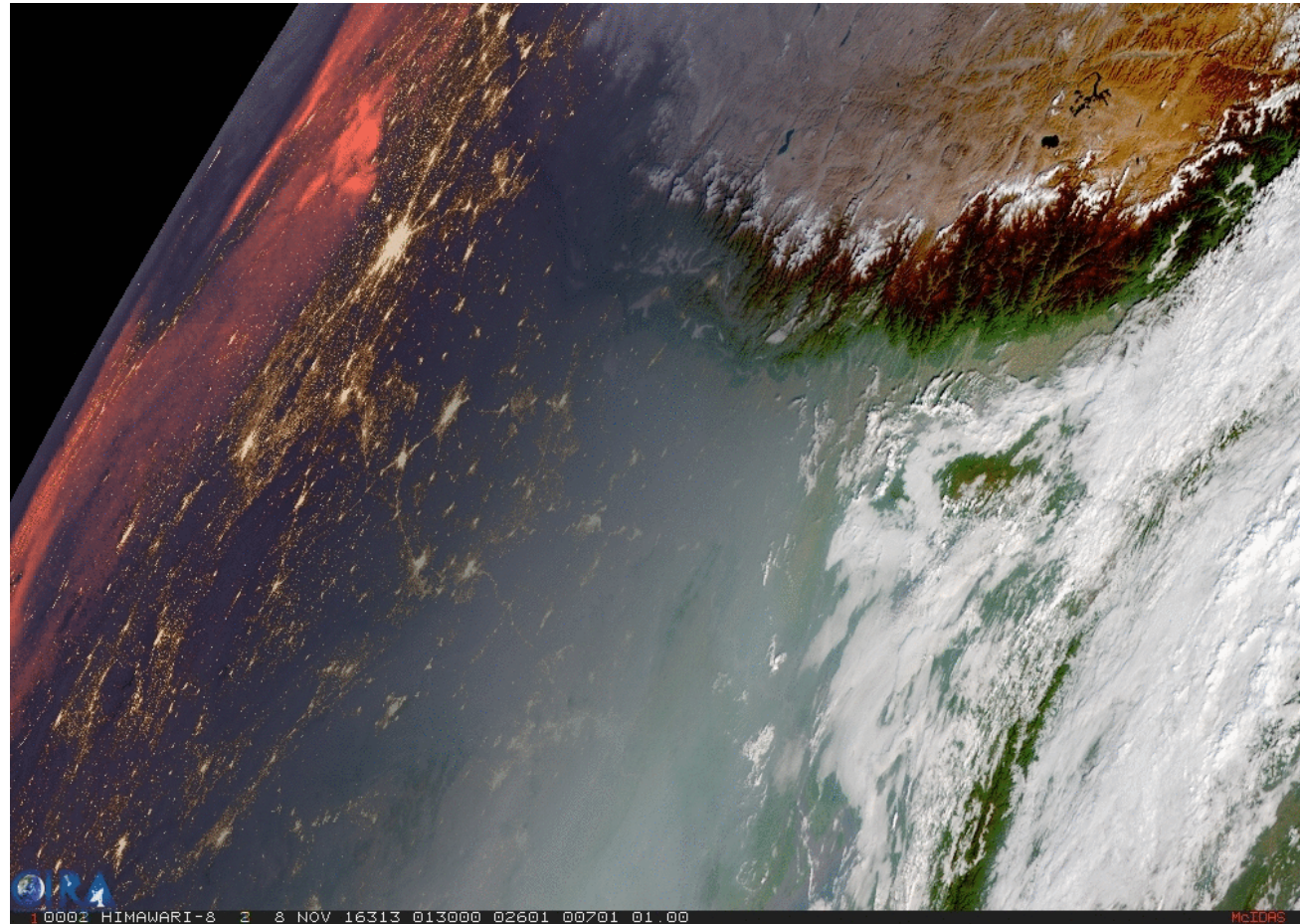
**Search**

**Fast Search for All Plumes in a Clicked Region**



# HIMAWARI-8

Smoke and smog over India – 11/8/2016

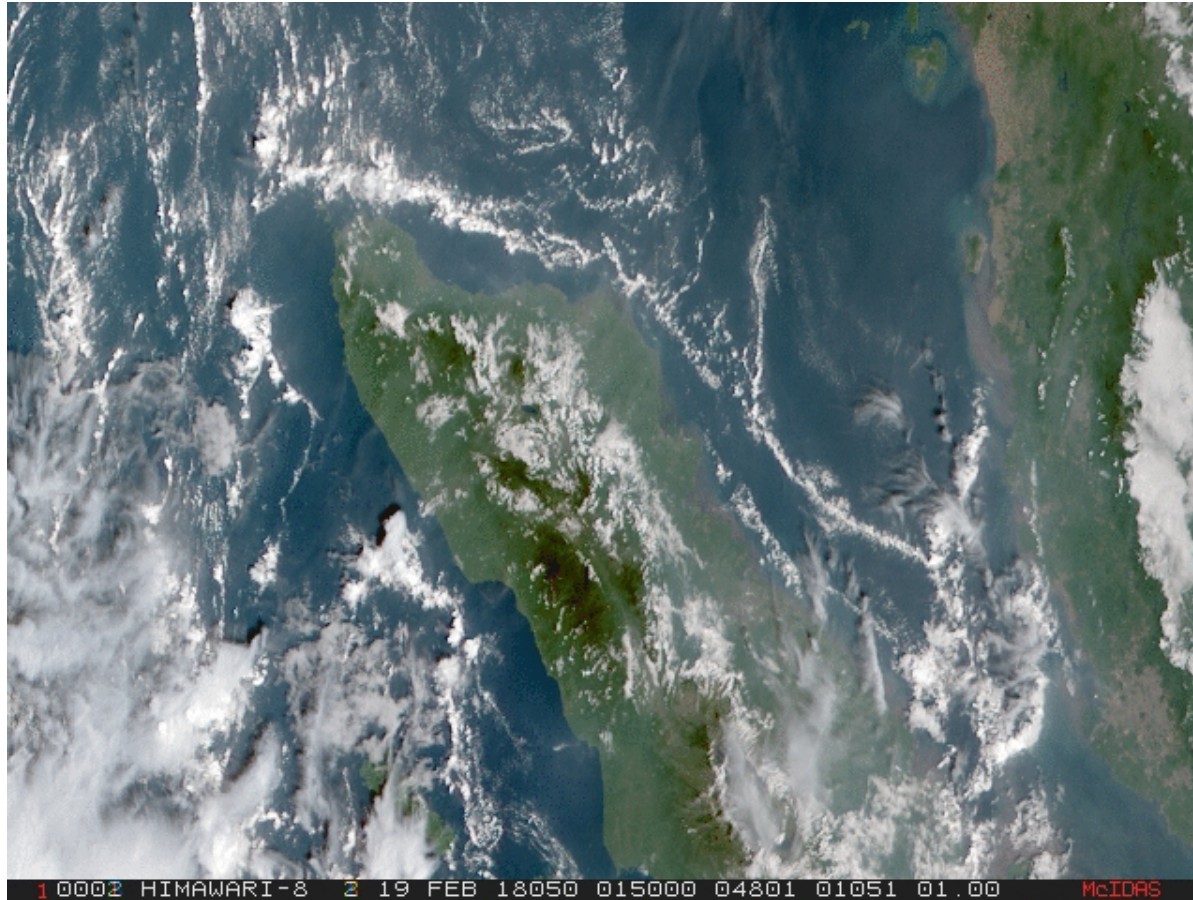


[http://rammb.cira.colostate.edu/ramsd/online/images/loop\\_of\\_the\\_day/himawari/20161108000000/video/20161108000000\\_india.gif](http://rammb.cira.colostate.edu/ramsd/online/images/loop_of_the_day/himawari/20161108000000/video/20161108000000_india.gif)



# HIMAWARI-8

## Eruption of Sinabung – 2/19/2018



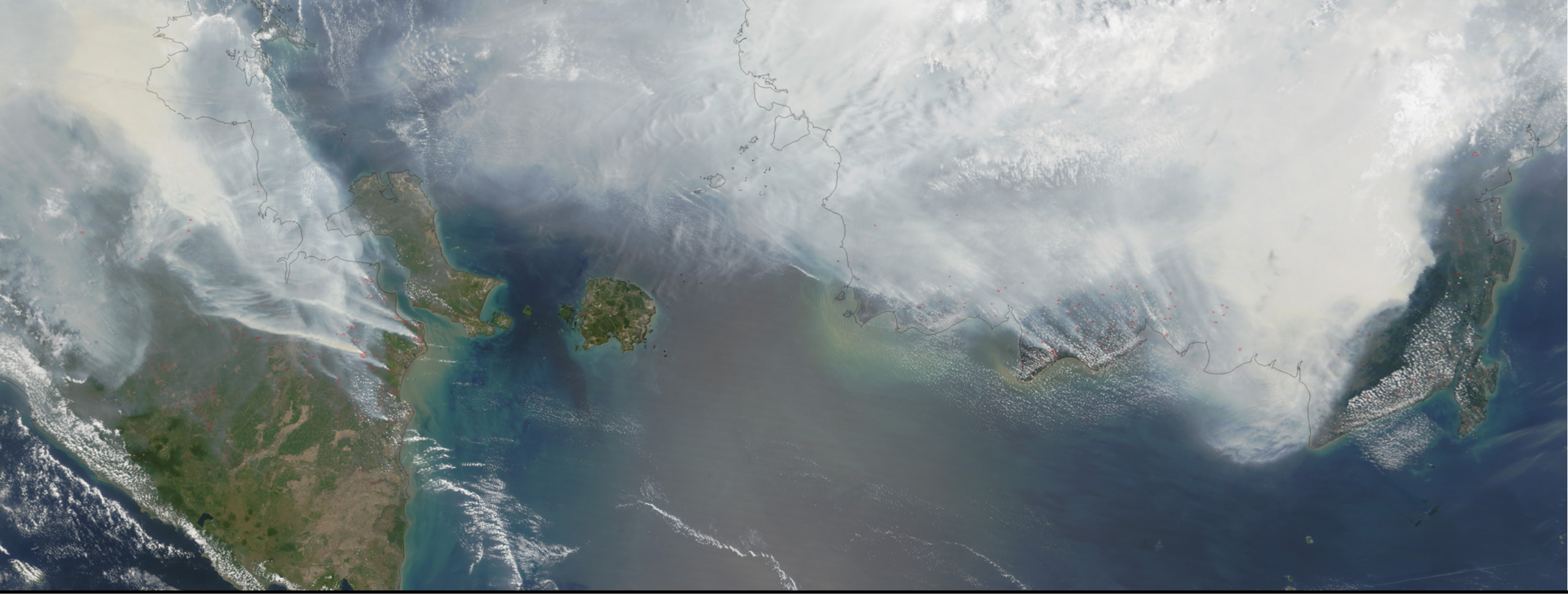
[http://rammb.cira.colostate.edu/ramsdisk/online/images/loop\\_of\\_the\\_day/himawari/20180219000000/video/20180219000000\\_sinabung.gif](http://rammb.cira.colostate.edu/ramsdisk/online/images/loop_of_the_day/himawari/20180219000000/video/20180219000000_sinabung.gif)



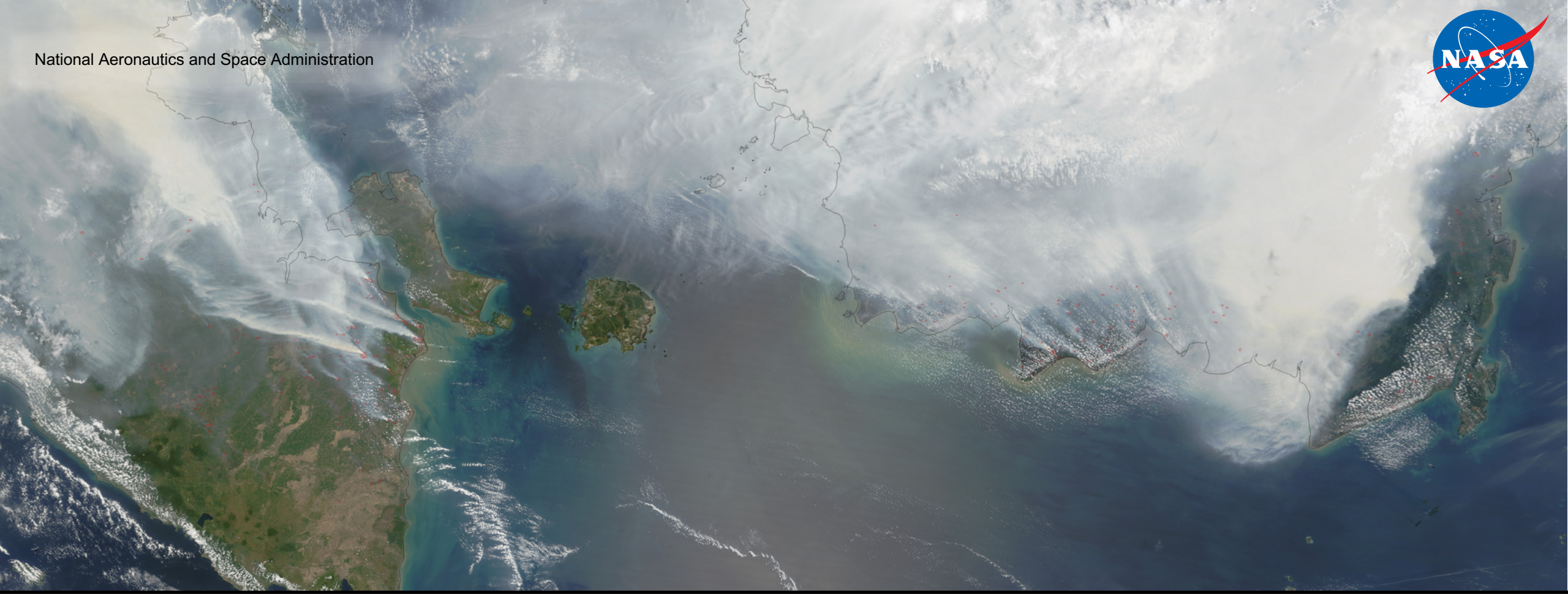
# Other Tools

- NASA's GEOS-5 Aerosol Forecasts: <https://portal.nccs.nasa.gov/cgi-bin/2dchem.cgi>
  - Click on the 7-SEAS region
- NRL Forecasts: <https://www.nrlmry.navy.mil/aerosol/#currentaerosolmodeling>





Questions?



# Satellite Based Fire Products: Methods, Data Access, and Applications

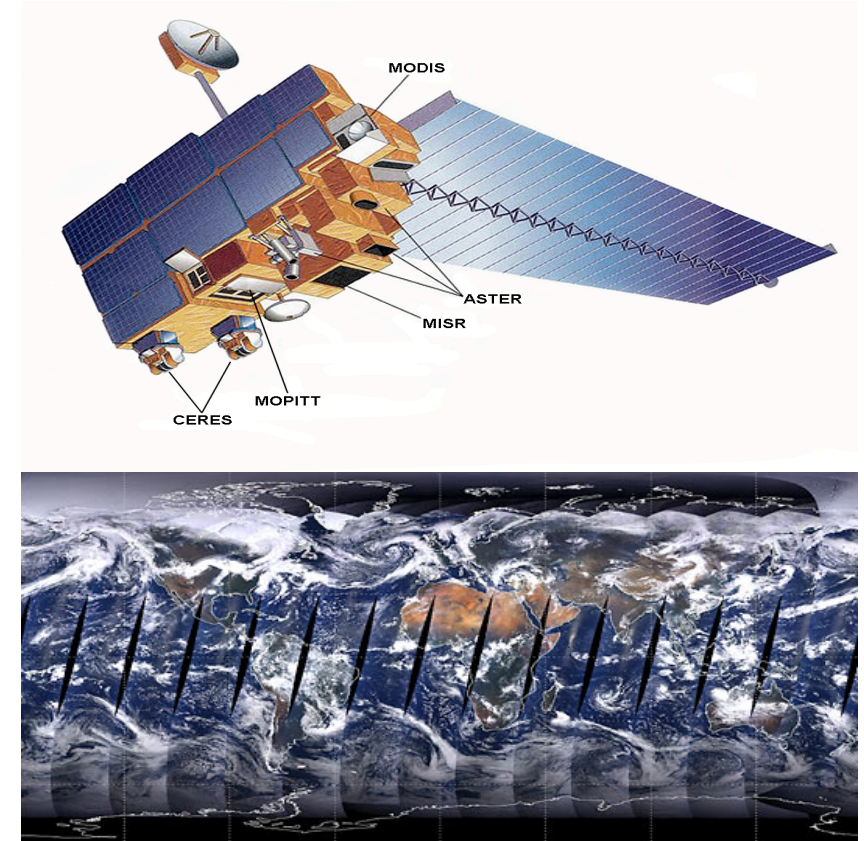
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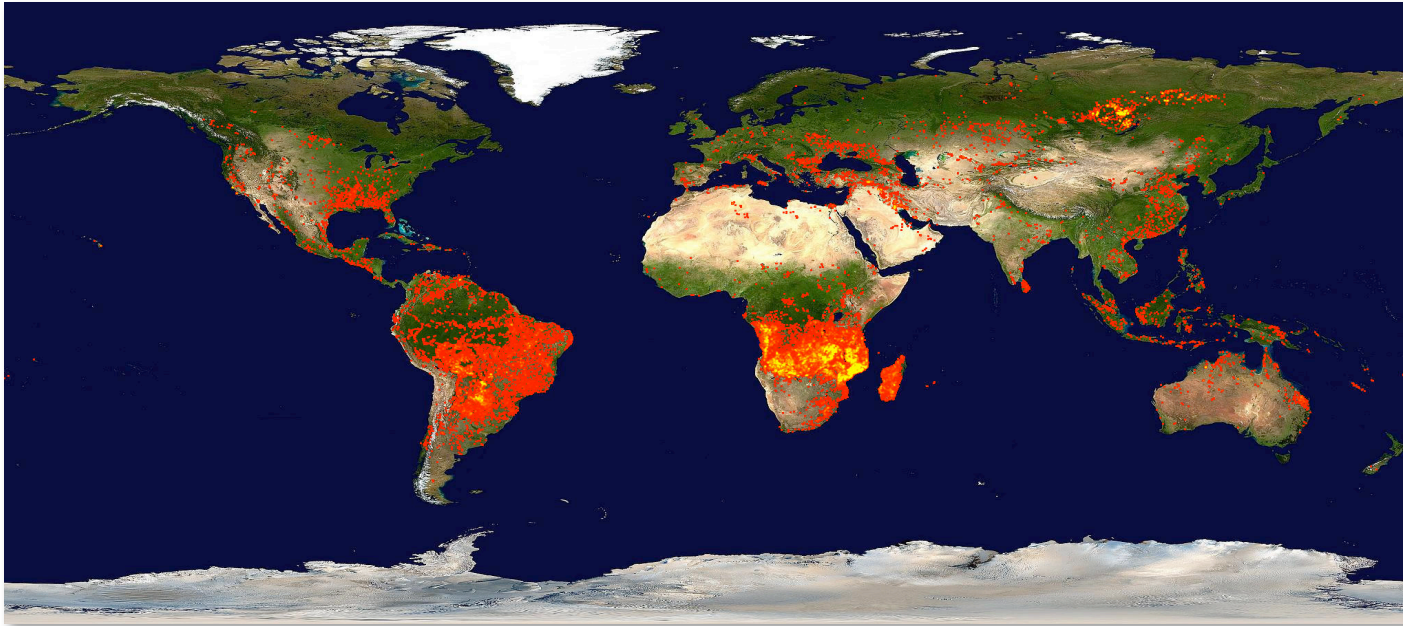
# MODIS

- Spatial Resolution
  - 250 m, 500 m, 1 km
- Temporal Resolution
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000–present
- Data Format
  - Hierarchical data format – Earth Observing System Format (HDF–EO8)
- Spectral Coverage
  - 36 bands (major bands include red, blue, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1000 m



# MODIS Active Fire Products (MOD04A1/MYD04A1)

- Near Real-Time (NRT) thermal anomalies and fire locations
- Provides snapshots of active burning fires and burned areas
- The Active Fire product delivers actively burning locations on a daily basis at 1 km resolution (additional 8 day and monthly products)



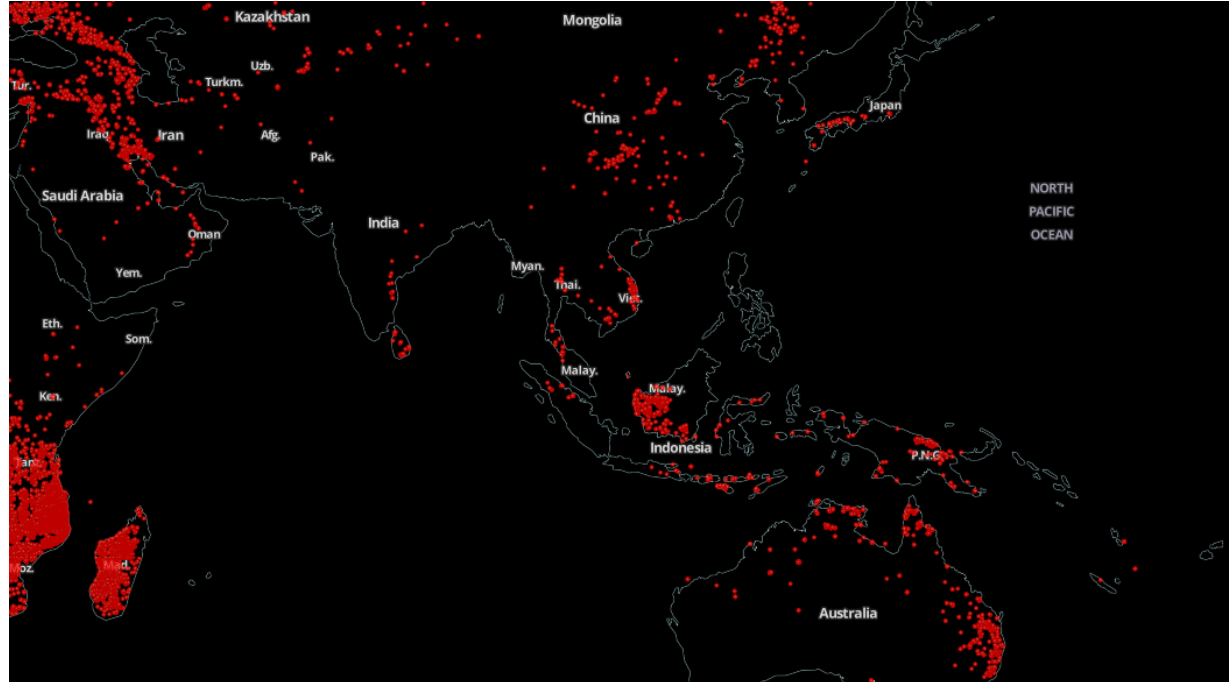
**Global Fire Map  
(September 17 – 26, 2016)**

Colors range from red, where the fire count is low, to yellow where the number of fires is large



# MODIS Thermal Anomalies Algorithm

- MODIS Fire Detection:
  - 1 km pixel flagged as containing one or more fires
  - can also detect volcanic signatures
- Significant increase in absolute radiance at 4  $\mu\text{m}$  (band 22) and 11  $\mu\text{m}$  (band 31)
  - cloud masks applied
  - VIIRS active fire detection algorithm is similar



VIIRS fire detections,  
NASA Worldview



# MODIS C6 Fire Detection Algorithm

<http://modis-fire.umd.edu/pages/manuals.php>

*Table 2: MODIS channels used for active-fire detection and characterization.*

Channel	Central wavelength (μm)	Purpose
1	0.65	Sun glint and coastal false alarm rejection; cloud masking.
2	0.86	Bright surface, sun glint, and coastal false alarm rejection; cloud masking.
7	2.1	Sun glint and coastal false alarm rejection.
21	3.96	High-range channel for fire detection and characterization.
22	3.96	Low-range channel for fire detection and characterization.
31	11.0	Fire detection, cloud masking.
32	12.0	Cloud masking.

- Potential fire pixel identified
  - $0.86 \text{ reflectance} < 0.35$
  - $BT4 > BT4^*$  (where  $300 \text{ K} \leq BT4^* \leq 330 \text{ K}$ )
  - $BT4 - BT11 > \Delta BT^*$  (where  $10 \text{ K} \leq \Delta BT^* \leq 35 \text{ K}$ )
- Otherwise flagged as non-fire pixel



# MODIS Thermal Anomalies Algorithm

- Limitations
  - False positives: small forest clearings (bare soil)
  - Large fire omissions due thick smoke
- Collection 6 (most recent) improves upon these errors
  - Global commission error of 1.2%

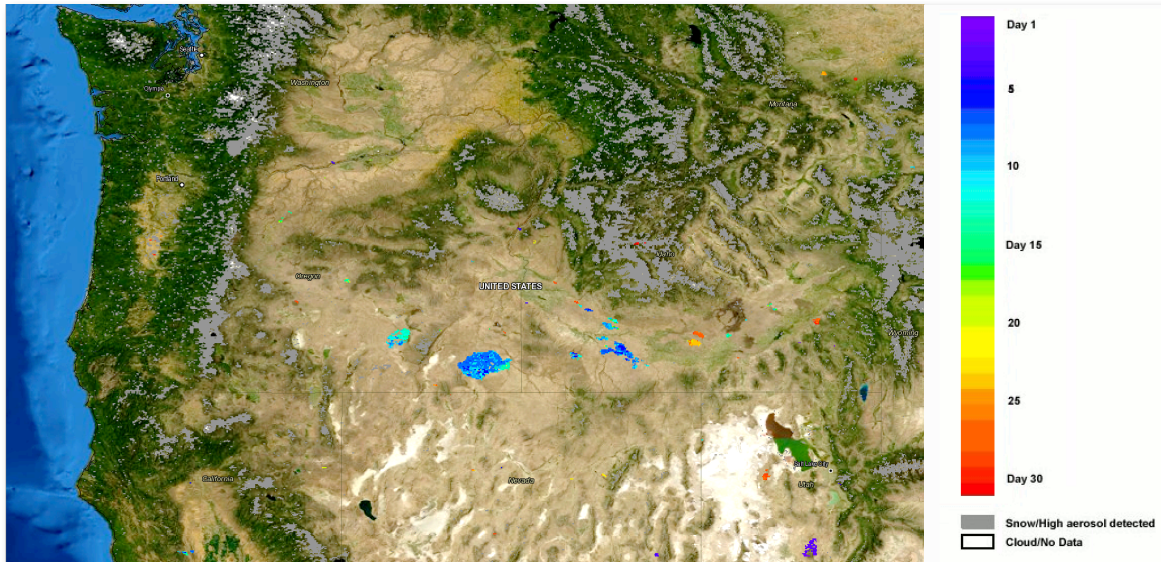


MODIS fire detections,  
NASA Worldview



# MODIS Land Products: Burned Area (MCD64A1)

- The combined Terra & Aqua MODIS Burned Area Product is a monthly gridded 500m product
- MODIS detects the approximate date of burning at 500m resolution
- Maps include the spatial extent of recent fires
- For more information: <http://modis-fire.umd.edu>



This image shows the extent of the Long Draw fire that occurred in southeastern Oregon

The colors represent the approximate day of the burning from July 8 (start of fire) to July 12, 2012 (end of fire)



# Where to Obtain MODIS Fire Products

## Archived data

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Land Process Distributed Active Archive (LPDAAC):  
<http://lpdaac.usgs.gov/>



NASA Earthdata: <https://earthdata.nasa.gov/>

## Near Real Time (NRT)

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Worldview: <http://worldview.earthdata.nasa.gov>  
(archived data also accessible)

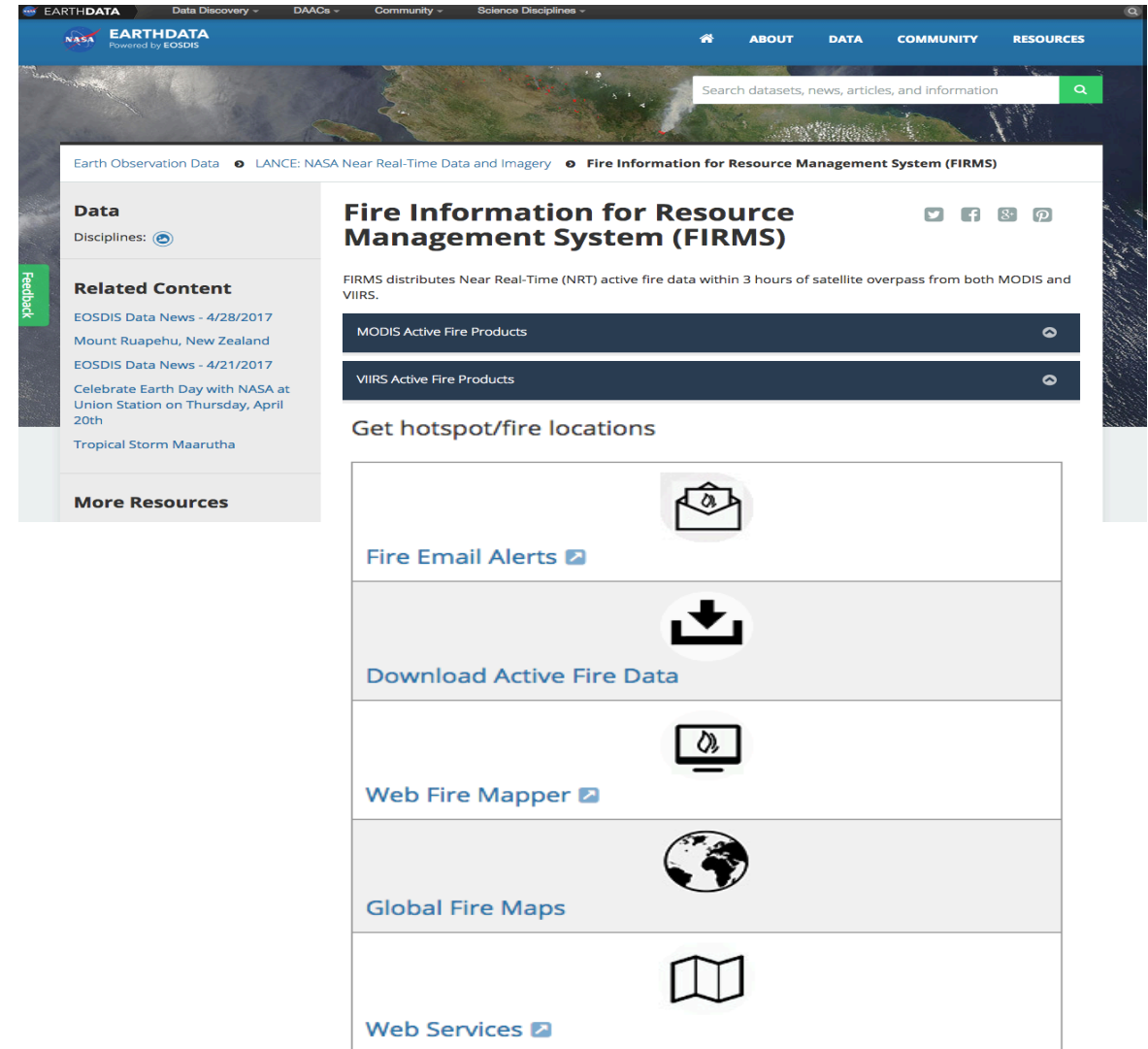


Fire Information for Resource Management System:  
<http://earthdata.nasa.gov/earth-observation-data/near-real-time/firms>



# Fire Information for Resource Management System (FIRMS)

- Near real-time (NRT) active fire data within 3 hours of satellite overpass
- Global MODIS and VIIRS fire locations
- Historical data available
- Available in:
  - Email alerts
  - GIS-friendly file format
  - Visualization in **Web Fire Mapper** or **Worldview**



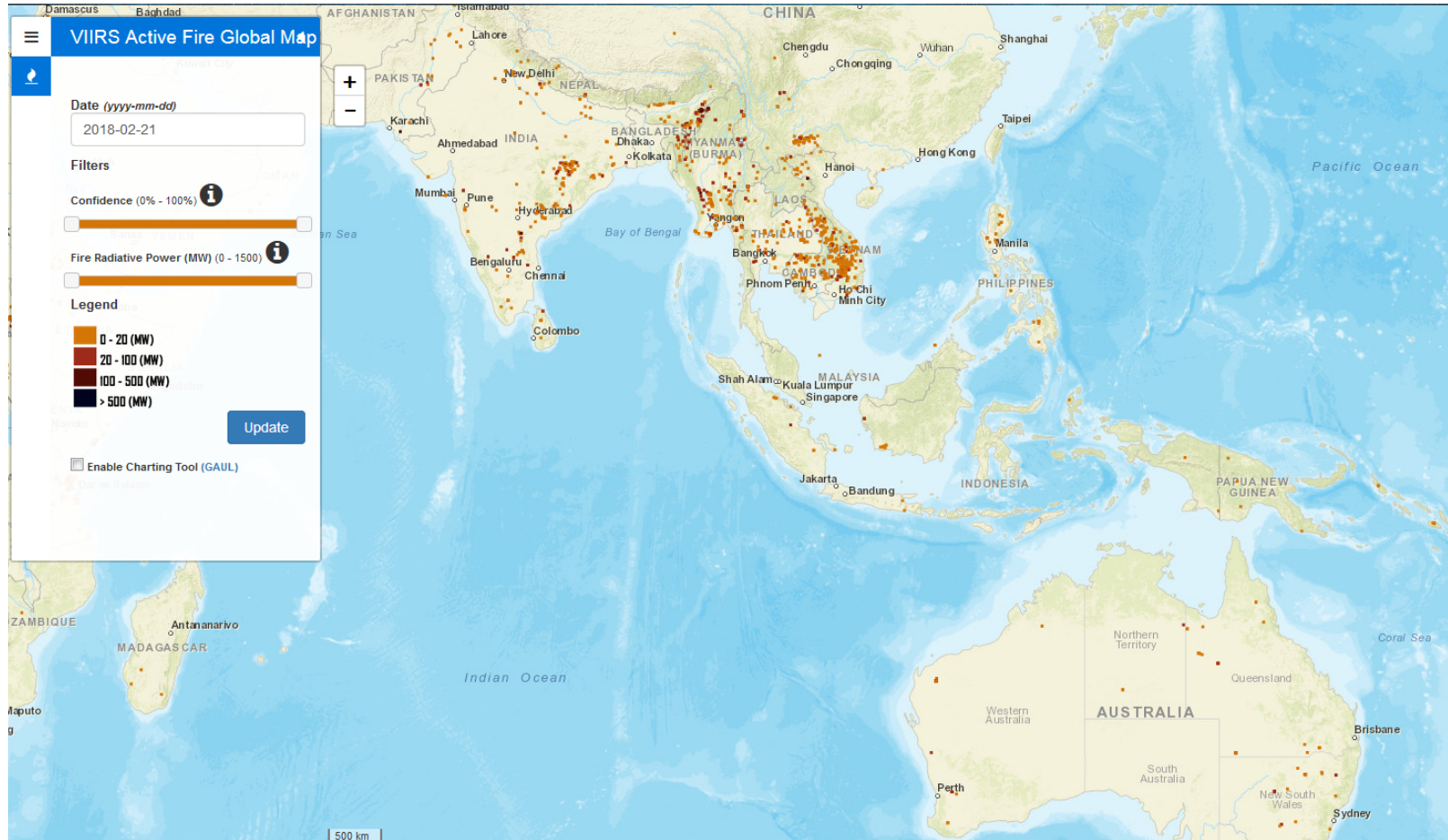
# VIIRS Active Fire Product

- Released October 22, 2012
- Spatial resolution:
  - 750 m (M-band)
  - 375 m (I-band)
- Data still preliminary and continually undergo evaluation & calibration
- Data available as:
  - ASCII
  - KMZ
  - TIFF
- Exercise on this tool in upcoming session



# VIIRS Active Fire Map

<http://viirsfire.geog.umd.edu/map/viirsMap.php>



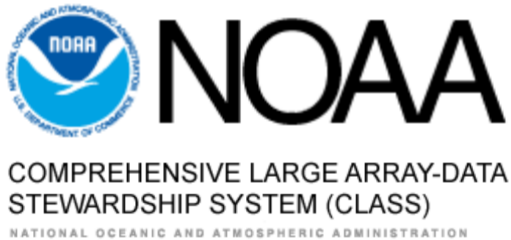
# Where to Obtain VIIRS Land Products



Worldview: <http://worldview.earthdata.nasa.gov>

VIIRS Active Fire

VIIRS Active Fire: <http://viirsfire.geog.umd.edu/pages/about.php>



NOAA Comprehensive Large Array-Data Stewardship System (CLASS):

<http://www.class.ngdc.noaa.gov/saa/products/welcome>

LAADS DAAC

Level-1 and Atmosphere Archive & Distribution System:

<http://ladsweb.nascom.nasa.gov>



# References

- User guides for the MODIS active fire and burned area products
  - <http://modis-fire.umd.edu/pages/manuals.php>
- VIIRS Active Fire page:
  - <http://viirsfire.geog.umd.edu/>
- NASA VIIRS Land Products
  - <https://viirsland.gsfc.nasa.gov/Products/NASA/NASAprd.html>



# Questions & Discussion Prompts

- Changes in what retrieved quantity are used to detect fires?
- What is a source of uncertainty for fire detection?

